

## (12) INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(19) World Intellectual Property  
Organization  
International Bureau



(43) International Publication Date  
9 June 2005 (09.06.2005)

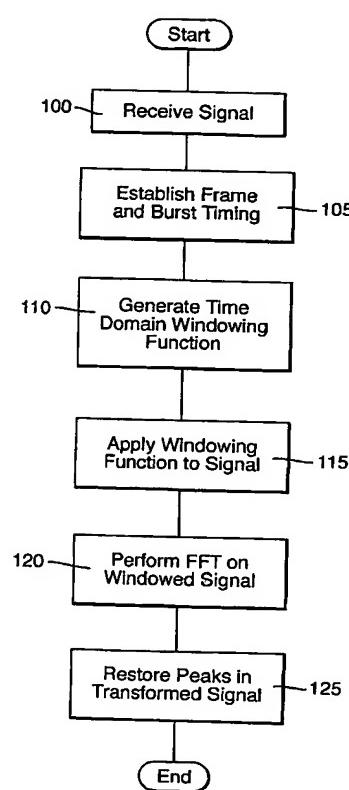
PCT

(10) International Publication Number  
**WO 2005/053175 A1**

- (51) International Patent Classification<sup>7</sup>: **H04B 1/58**
- (21) International Application Number:  
**PCT/GB2004/004921**
- (22) International Filing Date:  
19 November 2004 (19.11.2004)
- (25) Filing Language: English
- (26) Publication Language: English
- (30) Priority Data:  
0327041.0 21 November 2003 (21.11.2003) GB
- (71) Applicant (for all designated States except US): BAE SYSTEMS PLC [GB/GB]; 6 Carlton Gardens, London Greater London SW1Y 5AD (GB).
- (72) Inventor; and
- (75) Inventor/Applicant (for US only): RICHARDSON, Michael, Richard [GB/GB]; 16 Knyght Close, Romsey Hampshire SO51 5UX (GB).
- (74) Agents: MACKETT, Margaret, Dawn et al.; BAE SYSTEMS plc, Group IP Department, Lancaster House, P.O. Box 87, Farnborough Aerospace Centre, Farnborough Hampshire GU14 6YU (GB).
- (81) Designated States (unless otherwise indicated, for every kind of national protection available): AE, AG, AL, AM, AT, AU, AZ, BA, BB, BG, BR, BW, BY, BZ, CA, CH, CN, CO, CR, CU, CZ, DE, DK, DM, DZ, EC, EE, EG, ES, FI, GB, GD, GE, GH, GM, HR, HU, ID, IL, IN, IS, JP, KE, KG, KP, KR, KZ, LC, LK, LR, LS, LT, LU, LV, MA, MD, MG, MK, MN, MW, MX, MZ, NA, NI, NO, NZ, OM, PG, PH, PL, PT, RO, RU, SC, SD, SE, SG, SK, SL, SY, TJ, TM, TN, TR, TT, TZ, UA, UG, US, UZ, VC, VN, YU, ZA, ZM, ZW.
- (84) Designated States (unless otherwise indicated, for every kind of regional protection available): ARIPO (BW, GH, GM, KE, LS, MW, MZ, NA, SD, SL, SZ, TZ, UG, ZM, ZW), Eurasian (AM, AZ, BY, KG, KZ, MD, RU, TJ, TM), European (AT, BE, BG, CH, CY, CZ, DE, DK, EE, ES, FI, FR, GB, GR, HU, IE, IS, IT, LU, MC, NL, PL, PT, RO, SE, ZW).

[Continued on next page]

(54) Title: SUPPRESSION OF UNWANTED SIGNAL ELEMENTS BY SINUSOIDAL AMPLITUDE WINDOWING



(57) Abstract: A method is provided for processing a signal containing (100) regular or quasi-regular elements of unwanted signal, the method comprising the steps of: establishing timing characteristics of the unwanted signal elements in a portion of said signal (105); generating a time domain window function using said established timing characteristics (110); and applying the generated window function to said signal portion to selectively reduce the amplitude of said unwanted signal elements relative to other elements of said signal (115). Preferably the method includes applying an algorithm to restore the positions and amplitudes of spectral peaks in a frequency domain representation of the windowed signal (120, 125).



SI, SK, TR), OAPI (BF, BJ, CF, CG, CI, CM, GA, GN, GQ,  
GW, ML, MR, NE, SN, TD, TG).

*For two-letter codes and other abbreviations, refer to the "Guidance Notes on Codes and Abbreviations" appearing at the beginning of each regular issue of the PCT Gazette.*

**Published:**

- *with international search report*
- *before the expiration of the time limit for amending the claims and to be republished in the event of receipt of amendments*

## SUPPRESSION OF UNWANTED SIGNAL ELEMENTS BY SINUSOIDAL AMPLITUDE WINDOWING

The present invention relates to a method for processing a signal containing interference and, in particular, to a method for processing a signal  
5 containing bursts of regular or quasi-regular interference.

In certain types of signal, effects arising from certain types of interference burst contained within the signal cannot be removed entirely unless each of the bursts can be substituted by an accurate estimate of the original signal waveform in the corresponding regions of the signal. This may be possible to an  
10 acceptable degree of precision when a wanted signal is strong and not corrupted by noise, but in the case where the wanted signal is weak and not visible above the level of the noise or of other unwanted signals, substitution cannot necessarily be performed. It should also be noted that simple excision of the interference bursts is ineffective since this merely has the effect of replacing  
15 one interfering signal with another.

It is increasingly common for signal processing to be carried out digitally in the frequency domain, in modems for example. Certain types of regular or quasi-regular interference burst contained in signals, when processed in the frequency domain, can be particularly disruptive. A common source of such  
20 interference is ignition noise generated within motor vehicle engines. However, while the effects of such interference are particularly noticeable in frequency domain signal processing, equivalent degradation may also arise in time domain processing of such signals and the principles of the present invention may also be applied to such applications.

According to a first aspect of the present invention, there is provided a method for processing a signal containing regular or quasi-regular elements of unwanted signal, the method comprising the steps of:

- (i) establishing timing characteristics of the unwanted signal elements in a portion of said signal;
- 30 (ii) generating a time domain window function using said established timing characteristics; and

- 2 -

(iii) applying the generated window function to said signal portion to selectively reduce the amplitude of said unwanted signal elements relative to other elements of said signal.

Preferably, the generated time domain window function is a sinusoidal  
5 function. In other applications, different window functions may be selected according to the specific requirements of the application.

In a preferred embodiment, the method further comprises the steps of:

- (iv) applying a Fourier transform or similar spectral analysis process to the signal output from step (iii); and  
10 (v) applying an algorithm to restore the shape of spectral peaks in the transformed signal to an approximation of their form in the absence of said unwanted signal elements.

One of the advantages of using a sinusoidal windowing function is that although spectral peaks in the transformed signal tend to be split into sub-peaks  
15 as a result of the modulation applied by the windowing function, only two sub-peaks are created of equal amplitude are created. It is then a simple task to recombine such peak pairs in frequency and amplitude and restore them to a close approximation of signal spectrum that would have been expected in the absence of the application of the windowing function. Other windowing functions  
20 may yield a larger number of sub-peaks or other spectral profiles that would be less easy to restore.

A preferred embodiment of the present invention will now be described, by way of example only, with reference to the accompanying drawings of which:

Figure 1 is a flow diagram showing the steps in a signal interference  
25 reduction process according to a preferred embodiment of the present invention;

Figure 2 is a representation of a portion of a test signal containing one burst of interference;

- 3 -

Figure 3 is a representation of the signal of Figure 2 following application of a windowing function generated according to a preferred embodiment of the present invention;

5       Figure 4 is a representation of a received signal portion following application of a fast Fourier transform; and

Figure 5 is a representation of the result of applying an FFT to the same signal as used to generate Figure 2, but to which a windowing function, generated according to preferred embodiments of the present invention, has been applied prior to application of the FFT.

10       The steps in operation of a preferred method for processing a signal containing regular or quasi-regular bursts of interference will now be described with reference to Figure 1. This method may be applied in a variety of signal processing applications, particularly when processing in the frequency domain where this type of regular interference burst can tend to mask weaker signals  
15       during certain stages in the processing of the signal, especially by creating a "fence" of sidelobe peaks across the entire frequency spectrum of the signal.

Referring to Figure 1, at STEP 100, a signal to be processed is received. An example of a portion of a signal of interest is shown in Figure 2 in which an interference burst can be seen to manifest itself as a notch 200 in the signal envelope. Having received the signal, or at least a portion of it, the first task, at STEP 105, is to establish the locations of the interference bursts contained in the received signal. It may be that the source of interference is unknown and hence the only information available on the timing of the interference bursts is that derivable from an analysis of the signal. However, if the interference source  
25       is known, then a certain amount of such information may be extracted from a knowledge of the source. For example, in mobile communications systems such one conforming to the Global System for Mobile (GSM) standards, while signals generally comprise modulated sequences of symbols with a pseudo-random structure, at predefined intervals bursts of signal may be inserted for particular  
30       purposes such as frequency correction or synchronisation. Such bursts may not contain sequences of symbols with the pseudo-random properties encountered

- 4 -

in the majority of the signal. If the signal is being processed using, for example correlation techniques, which depend for their effectiveness on the general pseudo-randomness of the symbol stream, the occurrence of such bursts can generate interference effects of the type addressed by this invention. However,  
5 the structure and formatting of such interference-generating signal bursts are defined in the signal standards and well known procedures exist for the location of such bursts in received signals of this type.

Having established the locations of the interference bursts in the received signal, the next step, STEP 110, is to generate a time domain window  
10 function based upon the timing information established at STEP 105. Once generated, the purpose of this window function is to effect a preferential reduction in the amplitude of the received signal in the regions of the interference bursts. Preferably, a sinusoidal window function is generated having zero crossings arranged to coincide with the mid-points of the  
15 interference bursts. However, other types of window function may be used as would be apparent to a person of ordinary skill in the field of signal processing.

Having generated an appropriate window function at STEP 110 for at least a portion of the received signal then, at STEP 115, the window function is aligned with and applied to the received signal, essentially by multiplication of  
20 signal by the window function. In the case of the example signal shown in Figure 2, the result of applying a sinusoidal window function to that signal is shown in Figure 3. Referring to Figure 3, it can be seen that the received signal has taken on a sinusoidal amplitude weighting in which the region of signal having the interference burst 200 has been reduced in amplitude, locally to zero  
25 at the centre point of the burst. This process is mathematically equivalent to the application of suppressed carrier double sideband amplitude modulation to the signal, and is responsible for the peak splitting effect in the spectra of signals to which such windowing has been applied.

If, in processing a received signal in the frequency domain, a fast Fourier  
30 transform (FFT) or similar spectral analysis process were to be applied to the signal as received, then regular interference bursts would tend to result in a transformed signal comprising a "fence-like" series of spikes with a frequency

- 5 -

spacing corresponding to the repetition rate of the interference bursts in the time domain. In some cases such spikes can tend to mask the underlying signals. An example of the result of applying an FFT to a portion of received signal containing a regular interference burst is shown in Figure 4. As can be  
5 seen, the spikes 400 generated as a result of transforming the interference bursts are particularly noticeable. However, if a windowing function is generated and applied as described above with reference to steps 110 and 115 of Figure 1, to the signal portion of Figure 4, the result of applying the FFT to the resultant windowed signal is shown in Figure 5. Referring to Figure 5, it can be  
10 seen that the effect of the interference bursts has been greatly reduced. However, peaks in the transformed signal have tended to split into two sub-peaks, 500. This characteristic arises specifically from the application of a sinusoidal windowing function. However, is it a relatively easy task to recombine associated peak pairs in frequency and amplitude within the transformed signal  
15 when the peak as intended has been split into only two sub-peaks, and the spectral splitting characteristics are a simple function of the repetition rate of the interference bursts. This is an advantage of using the preferred sinusoidal windowing function.

Referring again to Figure 1, at STEP 120 a fast Fourier transform (FFT)  
20 is applied to the resultant signal from STEP 115. If, as discussed above in the example of figures 4 and 5, peaks in the transformed signal have been split into two sub-peaks, then at STEP 125, a simple algorithm may be executed to restore the peaks to an approximation of their original form, for example through the use of standard modulation theory for the analysis of the effect of applying a  
25 defined amplitude weighting to a signal and knowledge of the frequency of that signal, obtained from the known repetition rate of the interference bursts on the original signal.

It will be appreciated that the invention has been described by way of example only and that variation to the above described embodiments may be  
30 made without departing from the scope of the invention.

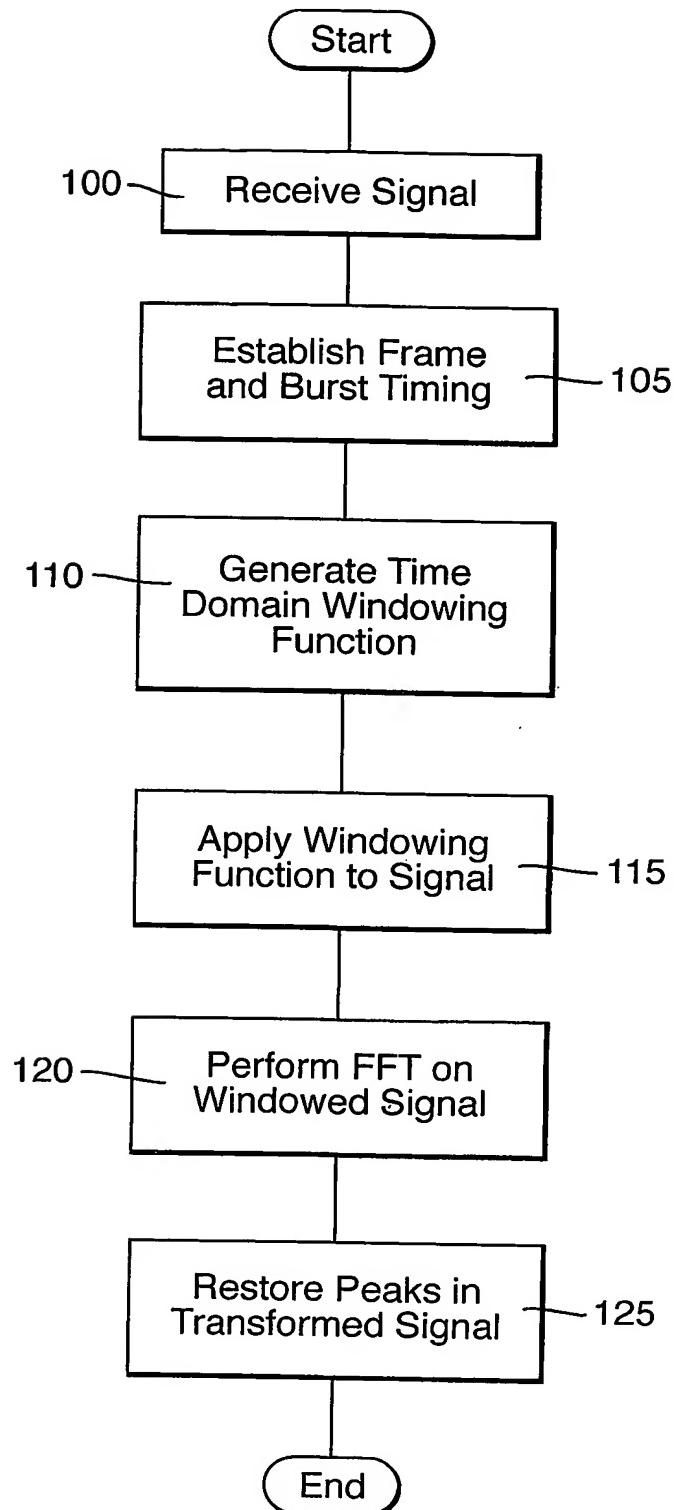
- 6 -

## CLAIMS

1. A method for processing a signal containing regular or quasi-regular elements of unwanted signal, the method comprising the steps of:
    - 5 (i) establishing timing characteristics of the unwanted signal elements in a portion of said signal;
    - (ii) generating a time domain window function using said established timing characteristics; and
    - (iii) applying the generated window function to said signal portion to
  - 10 selectively reduce the amplitude of said unwanted signal elements relative to other elements of said signal.
- 15
2. A method according to Claim 1, wherein said time domain window function is a sinusoidal function.
3. A method according to Claim 1 or Claim 2, further comprising the steps of:
    - (iv) applying a Fourier transform to the signal output from step (iii); and
    - (v) applying an algorithm to restore the shape of peaks in the transformed
  - 20 signal to an approximation of their form in the absence of said unwanted signal elements.
4. A method according to Claim 2, wherein said sinusoidal window function is arranged to have a zero crossing substantially coinciding with the position of
  - 25 each unwanted signal element established at step (ii).

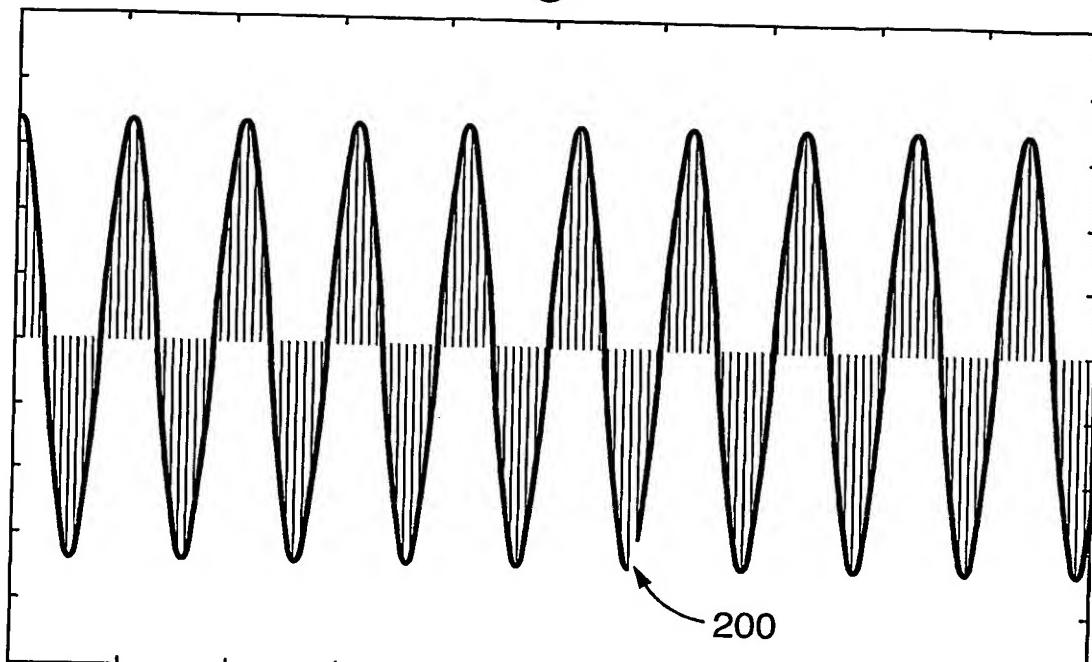
1/3

Fig. 1.



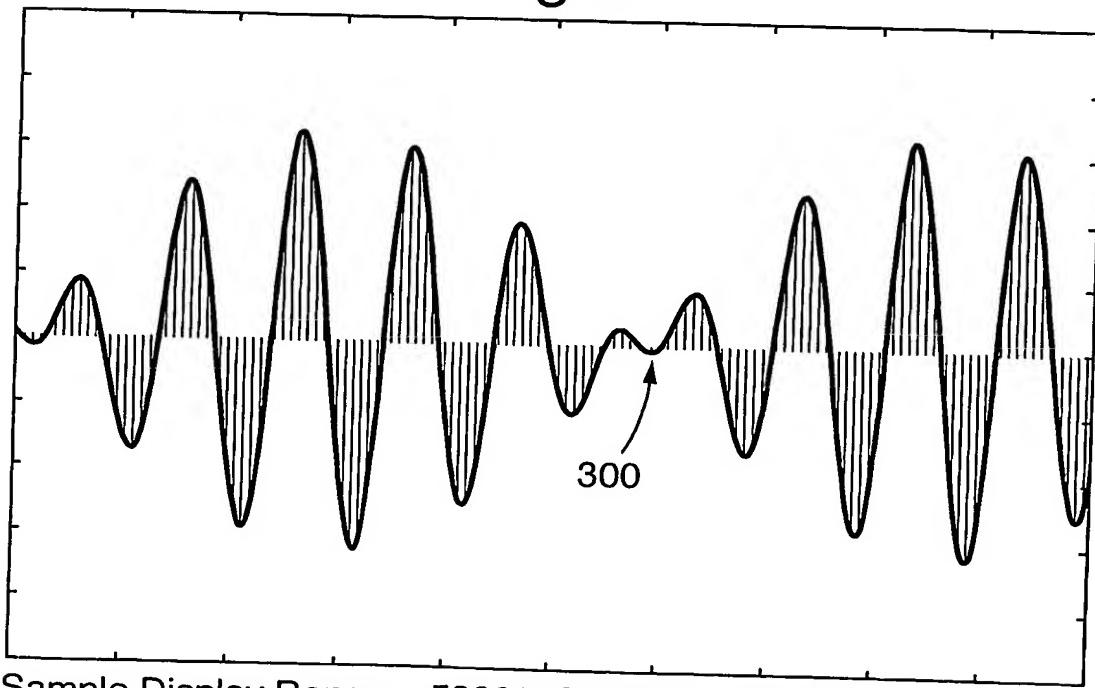
2/3

Fig.2.

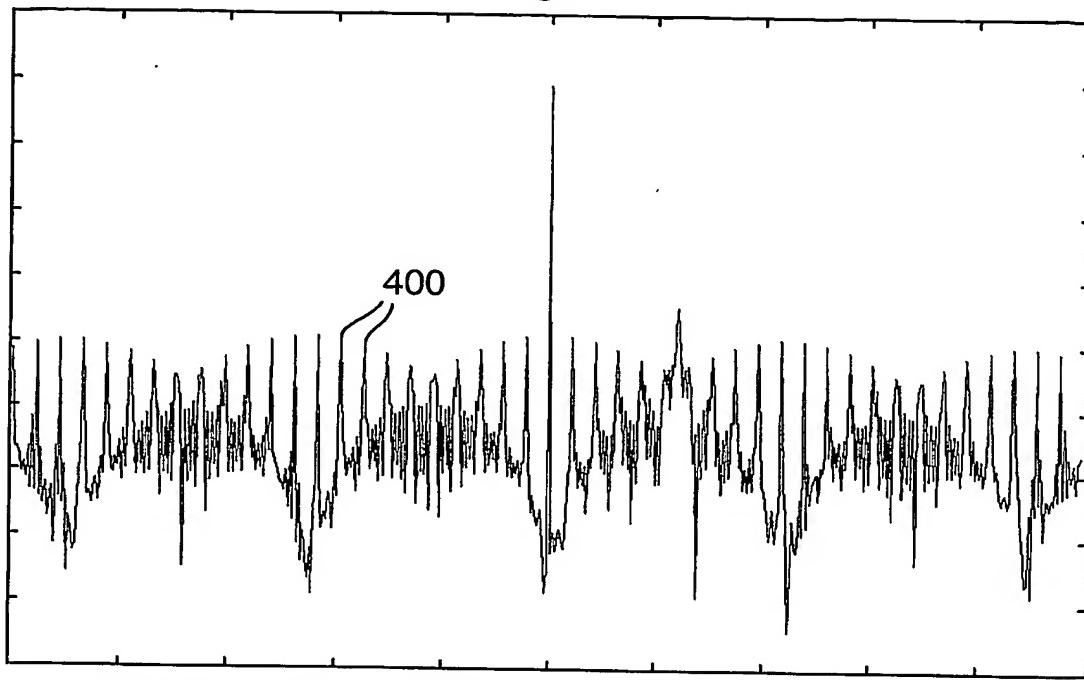


Sample Display Range = 50000, Step No = 0 0.000

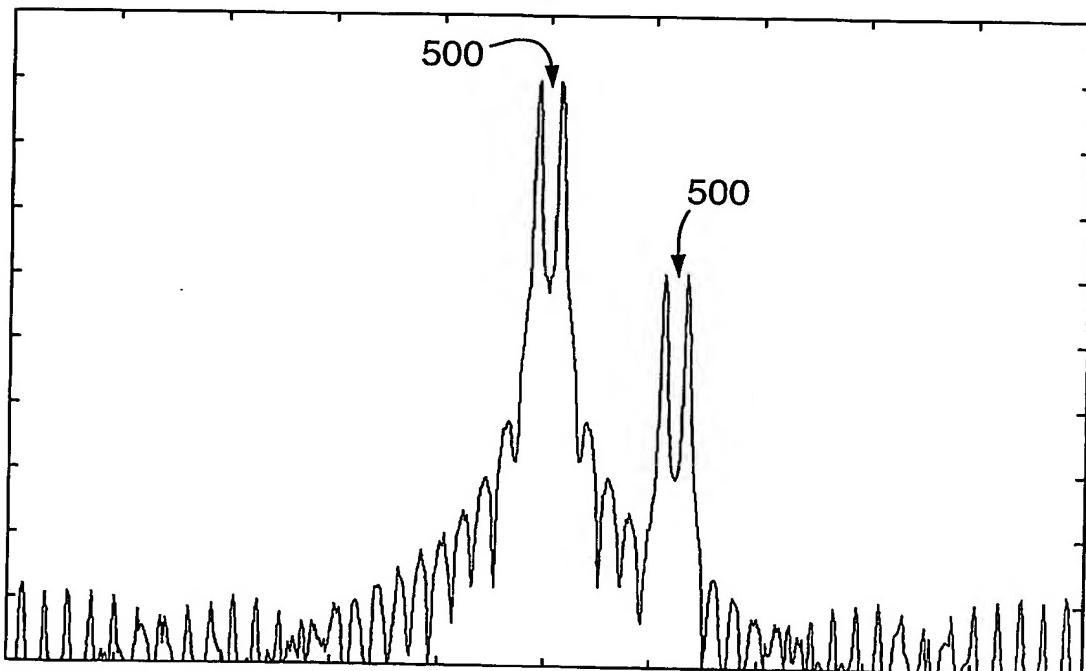
Fig.3.



Sample Display Range = 50000, Step No = 0 0.000

**Fig.4.**

FFT Display Range = 0->553m  
Vert Scale = 10dB/div Horiz Scale = 100Hz/div, Step No = 0

**Fig.5.**

FFT Display Range = 0->553m  
Vert Scale = 10dB/div Horiz Scale = 100Hz/div, Step No = 0

# INTERNATIONAL SEARCH REPORT

National Application No  
/GB2004/004921

**A. CLASSIFICATION OF SUBJECT MATTER**  
IPC 7 H04B1/58

According to International Patent Classification (IPC) or to both national classification and IPC

**B. FIELDS SEARCHED**

Minimum documentation searched (classification system followed by classification symbols)  
IPC 7 H04L H04B

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the International search (name of data base and, where practical, search terms used)  
**EPO-Internal, WPI Data, PAJ, INSPEC, COMPENDEX**

**C. DOCUMENTS CONSIDERED TO BE RELEVANT**

Category *	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 2002/176480 A1 (WHEATLEY CHARLES E ET AL) 28 November 2002 (2002-11-28) abstract	1, 2
A	paragraph '0076! - paragraph '0081! figure 8	3 4
X	US 5 287 387 A (BIRCHLER ET AL) 15 February 1994 (1994-02-15) abstract	1, 2
A	column 2, line 5 - line 34 figures 1-4	3, 4
X	EP 1 069 693 A (MITSUBISHI DENKI KABUSHIKI KAISHA) 17 January 2001 (2001-01-17) paragraph '0003! - paragraph '0008! figure 8	1
A		2-4
		-/-

Further documents are listed in the continuation of box C.

Patent family members are listed in annex.

\* Special categories of cited documents :

- "A" document defining the general state of the art which is not considered to be of particular relevance
- "E" earlier document but published on or after the international filing date
- "L" document which may throw doubts on priority, claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)
- "O" document referring to an oral disclosure, use, exhibition or other means
- "P" document published prior to the international filing date but later than the priority date claimed

- "T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
- "X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
- "Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art.
- "&" document member of the same patent family

Date of the actual completion of the International search

9 March 2005

Date of mailing of the International search report

29/03/2005

Name and mailing address of the ISA

European Patent Office, P.B. 5818 Patentlaan 2  
NL - 2280 HV Rijswijk  
Tel. (+31-70) 340-2040, Tx. 31 651 epo nl,  
Fax: (+31-70) 340-3016

Authorized officer

Marselli, M

# INTERNATIONAL SEARCH REPORT

International Application No

/GB2004/004921

C.(Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT		
Category	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	<p>SAUL A: "ANALYSIS OF PEAK REDUCTION IN OFDM SYSTEMS BASED ON RECURSIVE CLIPPING" INTERNATIONAL OFDM WORKSHOP, vol. 1, 24 September 2003 (2003-09-24), pages 103-107, XP008037944 HAMBURG, GERMANY</p>	3
A	<p>page 103, right-hand column, line 1 – page 104, left-hand column, line 38 figure 3</p> <p>-----</p>	1,2,4

**INTERNATIONAL SEARCH REPORT**

International Application No

/GB2004/004921

Patent document cited in search report	Publication date	Patent family member(s)		Publication date
US 2002176480	A1 28-11-2002	BR EP JP TW WO	0209955 A 1389365 A1 2004527978 T 577198 B 02095974 A1	24-08-2004 18-02-2004 09-09-2004 21-02-2004 28-11-2002
US 5287387	A 15-02-1994	NONE		
EP 1069693	A 17-01-2001	JP JP JP DE EP	2001036420 A 3465638 B2 2001036419 A 60014790 D1 1069693 A2	09-02-2001 10-11-2003 09-02-2001 18-11-2004 17-01-2001